2.0 GROUNDWATER DATA – COLLECTION AND CONCEPTUAL SITE MODEL

2.1 Data Collection and Literature Search

The data collection and literature search efforts were the first steps taken in conducting the groundwater evaluation. A comprehensive literature search was conducted to identify and obtain published research on Lake Tahoe studies involving geology, hydrogeology, geomorphology, nutrients sources, land use, groundwater modeling, behavior of nitrogen and phosphorous in groundwater, and remediation technologies. Over 300 literature sources were identified, and among those, several were carefully selected and reviewed.

The groundwater evaluation focused on a re-evaluation of existing data and a limited compilation of new data generated since the study conducted by Thodal (1997). The goals for the re-evaluation of existing data were to identify land use practices (current and historic) that could be contributing to nutrient loading to the groundwater system, and to develop an estimate for nutrient loading to Lake Tahoe transported through groundwater. Specific data collected included nutrient concentrations, groundwater flow characteristics, and geology available through records of public drinking water supply wells and groundwater monitoring wells. Other resources used were land use maps, aerial photographs, and Geographical Information System (GIS) layers.

Existing data was obtained from a number of different local, state, and federal agencies in California and Nevada. Among the agencies contacted, many were able to provide data which was valuable to this evaluation. There are still numerous studies currently being conducted in the basin which were not included. Some of this un-finalized data will become available in the near future, but not in time to contribute to this evaluation. Though most data obtained was in electronic form, there was a significant amount presented as hard copies. Some of the more manageable hard copy data was obtained and used in this evaluation. Some data needed to evaluate regional groundwater flow did not exist and additional field work and sample collection will be necessary to fill in those data gaps. In addition, not all land use types evaluated had associated groundwater nutrient data. In this instance, assumptions were made to estimate how specific land use types would affect nutrient loading.

Agencies contacted for data collection and information included but were not limited to the following: Lahontan Regional Water Quality Control Board, Tahoe Regional Planning Agency, University of California-Davis - Tahoe Research Group, University of Nevada-Reno, Desert Research Institute, California Tahoe Conservancy, US Forest Service, US Park Service, US Geological Survey, California Department of Health Services – Data Management Unit, California Department of Water Resources, California State Park Service, Nevada Bureau of Health Protection, Nevada Division of Environmental Protection, Nevada Division of Water Resources, Nevada Division of State Lands, Public Utility Districts (South Tahoe, Tahoe City, North Tahoe), General Improvement Districts (Incline Village, Kingsbury), City of South Lake Tahoe, El Dorado County Department of Transportation and Environmental Management, Placer County Environmental Management and Transportation Departments, Washoe County, Douglas

County, Lake Tahoe Transportation & Water Quality Coalition, South Tahoe Chamber of Commerce, The League to Save Lake Tahoe, and Entrix.

2.2 Historic Aerial Photography

Historical aerial photography was obtained from the U.S. Forest Service. This photography was obtained for Lake Tahoe Basin from 1966, 1968, and 1971. The photography was scanned and geo-referenced to the 1998 digital orthoquad. The developed areas were then determined based on roads and other features representing development. This was then used to determine where there could be septic tank leach fields remaining in the basin. These are important features as they could be continuous sources of nutrients to groundwater in the basin.

2.3 Land Use Classification

There are numerous land use classifications within the basin. The primary land uses of concern are residential, commercial, and recreational. These land use types can be sources of nutrients to the groundwater system. Because many of the regions did not have adequate monitoring networks, regional average concentrations for specific land use types were developed. Each well was assigned a land use code based upon its location. The analytical results for all wells of the same land use type were then compiled and average concentrations were determined (Table 2-1). The vegetated land use type was developed to show potential ambient conditions. However, because many urban lots are considered vegetated, this land use classification did not represent ambient conditions. A forested land use category was used to better represent background conditions of the basin.

When developing a basin-wide average for orthophosphorus and total dissolved phosphorus, the average orthophosphorus for most land use types (residential, recreational, commercial and vegetated) was higher than the total phosphorus concentration. This is likely due to many wells in the basin only being sampled for one form of phosphorus. To rectify this, all samples within the basin providing both an orthophosphorus concentration and total dissolved phosphorus concentration on the same sampling event were compiled. Each concentration was compared to develop the percent of orthophosphorus in each sample. The results showed an average of 74% of the total dissolved phosphorus was orthophosphorus. This percentage was then used to derive an estimated concentration for those sampling events where only one form of phosphorus was sampled. New averages for each land use type were then determined using the estimated concentrations. Those corrected values are listed in Table 2-1.

Table 2-1. Average Nutrient Concentrations Based on Land Use Types within the Tahoe Basin

Land Use/Tests Run	Nitrogen Ammonia plus Organic Dissolved (mg/l)	Nitrogen Nitrite plus Nitrate Dissolved (mg/l)	Total Dissolved Phosphorus (mg/l)	Dissolved Orthophosphorus (mg/l)
Residential	0.256	0.367	0.114	0.081
Commercial	0.158	0.512	0.124	0.092
Recreational	0.419	1.264	0.100	0.069
Vegetated	0.361	0.578	0.131	0.097
Forested	0.06	0.121	0.068	0.047

Notes:
1. All sources of data collected as part of this evaluation were used in developing the average concentrations.
2. The averages were based on anywhere from 40 to 590 sample results.

2.4 Conceptual Site Model

A conceptual site model for this evaluation was developed as an aid in explaining applicable chemical reactions of nitrogen and phosphorous, sources of those nutrients, the mediums through which nutrients are driven to the groundwater, and the pathways that the nutrients can take to reach the lake. A brief description of the hydrologic cycle is provided below as an aid in developing a conceptual site model of groundwater behavior in the Tahoe Basin.

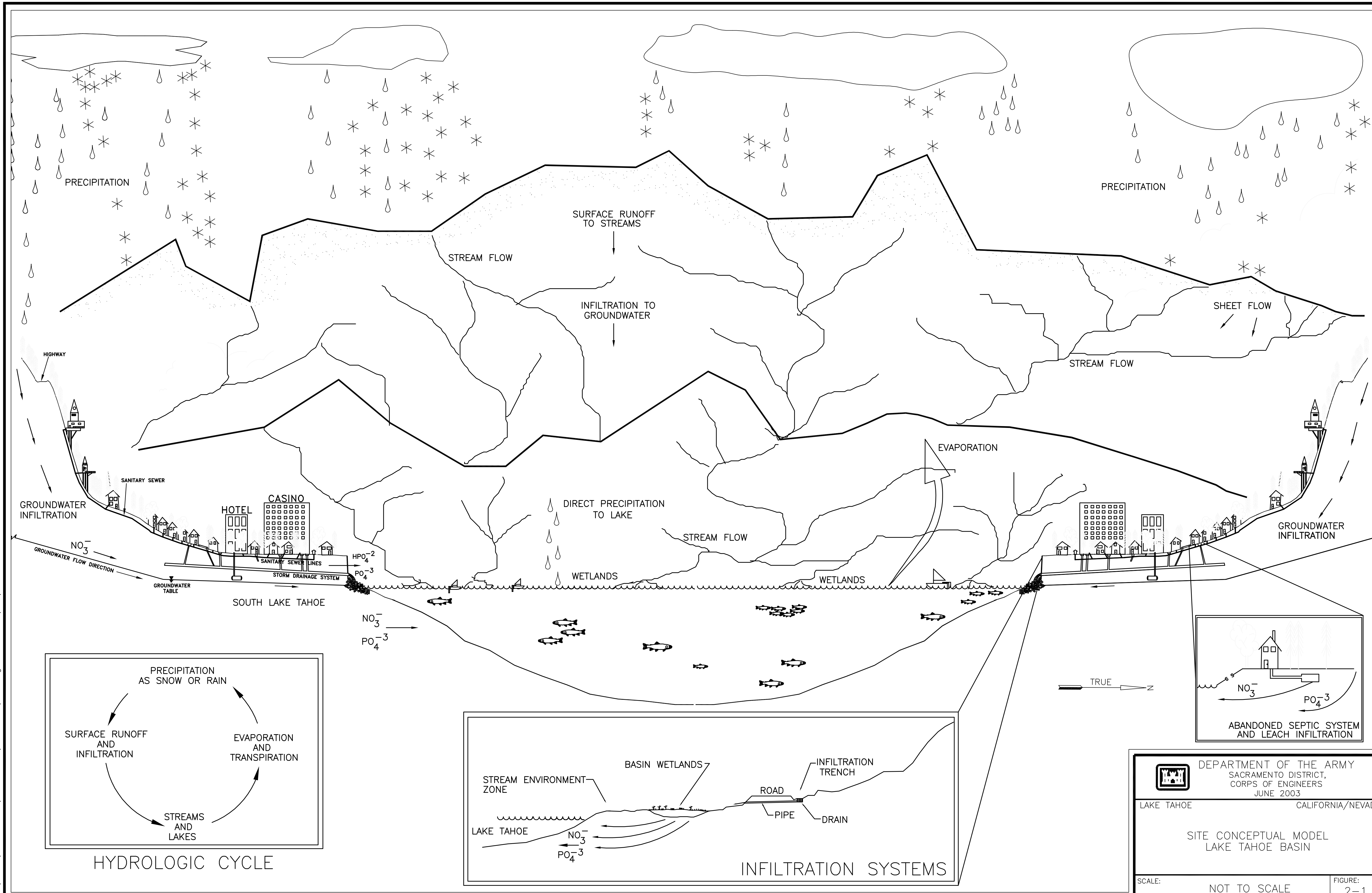
- Water vapor trapped in clouds precipitates as snow and rain.
- Surface runoff and groundwater discharge to rivers, streams, and eventually the lake.
- Evaporation and transpiration return water to the vapor state and complete the hydrologic cycle (Figure 2-1).

The Lake Tahoe Basin is 1,311 square kilometers (506 square miles) in area, of which the surface area of the lake itself is 40% of the total or 495 square kilometers (191 square miles). The dramatic topographic relief of the surrounding watersheds limits urban development to a few flat areas along streams and in wetlands. A recent study in the Basin estimates groundwater flows into Lake Tahoe at a rate of about 5.6×10^7 m^3/year (45,000 acre-feet per year) (Fogg 2002).

While 40% of precipitation in the Tahoe Basin falls into Lake Tahoe (USGS 2003), the remaining 60% of rain and snow is deposited in watersheds. Surface runoff flows into streams while groundwater infiltrates basin fill and fractured bedrock, with both eventually discharging to Lake Tahoe. The only outlet from Lake Tahoe is the Truckee River, which flows northeast from the lake through Reno, Nevada, and finally into Pyramid Lake.

Rainfall and snowmelt infiltrate the upland basin fill deposits and fractured rock. As groundwater infiltrates and travels downgradient, it passes through developed areas and co-mingles with infiltration from lower areas. Along the way, groundwater may be enriched with soluble nutrients through various processes. Among the major sources of these soluble nutrients are storm water infiltration basins, runoff from golf courses and parking lots, runoff from housing developments, and sewage and septic systems. The increasing rate of nutrient deposition to Lake Tahoe is affecting lake clarity by accelerating algal growth and eutrophication. Lake Tahoe is losing clarity at the rate of about 0.3 meters (1 foot per year) (Jassby et al. 2001).

Until 150 years ago, Lake Tahoe maintained an oligotrophic state because it received very low amounts of nutrients and sediments. The lake was both nitrogen- and phosphorus-limited. Logging during the last half of the nineteenth century caused a temporary decrease in clarity, but the lake recovered over a period of about 50 years. Starting around 1960, nitrogen loading from vehicle emissions and dissolved fertilizer created a high nitrogen to phosphorus ratio and caused the lake to shift to being phosphate-limited by about 1980 (Jassby et al. 2001). As expected in the eutrophication process, the flora and fauna of the lake are increasing in both population and diversity as a result of nutrient loading. Figure 2-1 illustrates a conceptual site model of groundwater and nutrient movement in the Tahoe Basin. The figure also includes detailed sketches of the hydrologic cycle, an abandoned septic system and its associated leach field, and an engineered infiltration system.



DEPARTMENT OF THE ARMY
SACRAMENTO DISTRICT,
CORPS OF ENGINEERS
JUNE 2003

LAKE TAHOE | CALIFORNIA/NEVADA

SITE CONCEPTUAL MODEL
LAKE TAHOE BASIN

SCALE: NOT TO SCALE

FIGURE: 2-1

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